Disentangling the roles of various forcing mechanisms on stratospheric temperature changes since 1979 with the NASA GEOSCCM

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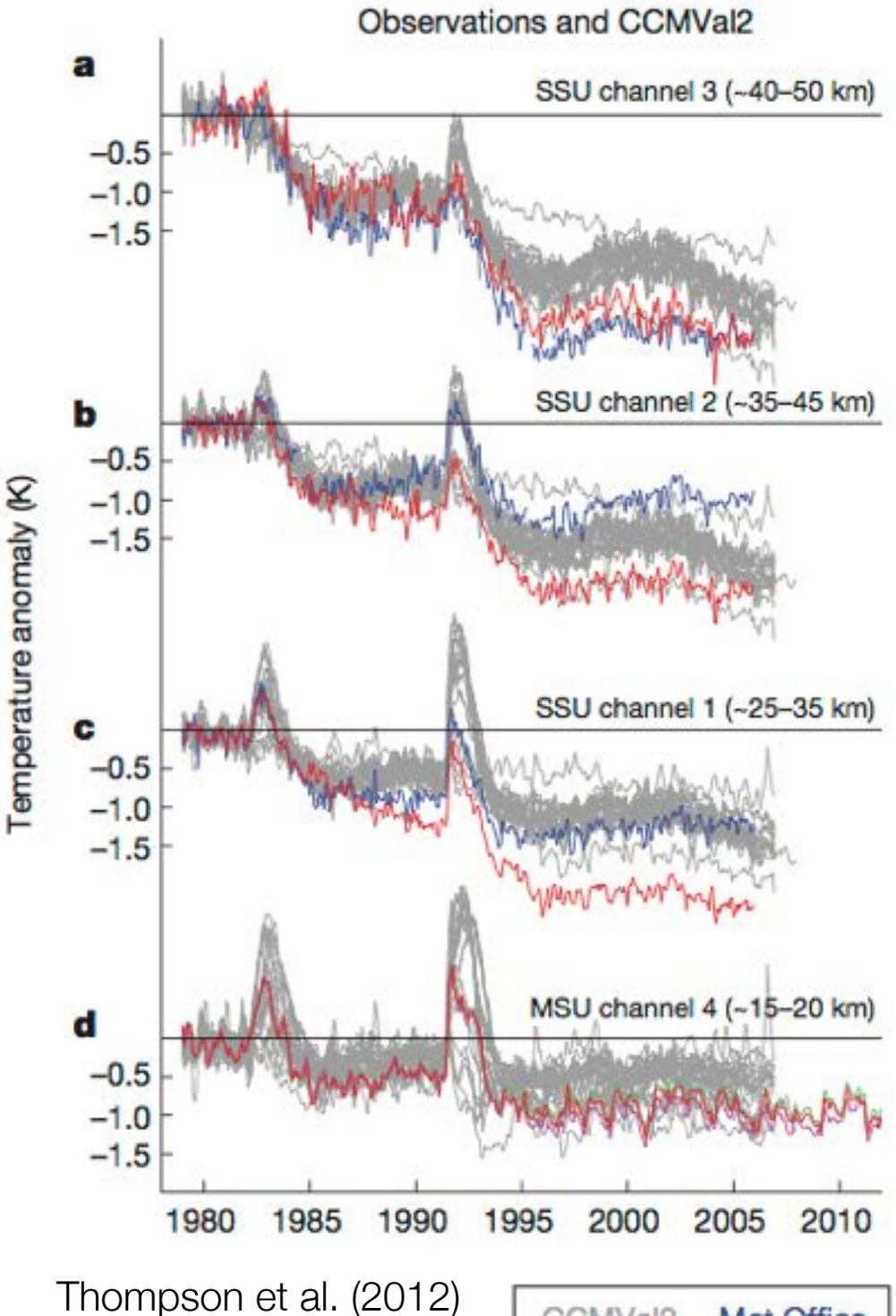
Global stratospheric temperature anomalies wrt 1979-1982

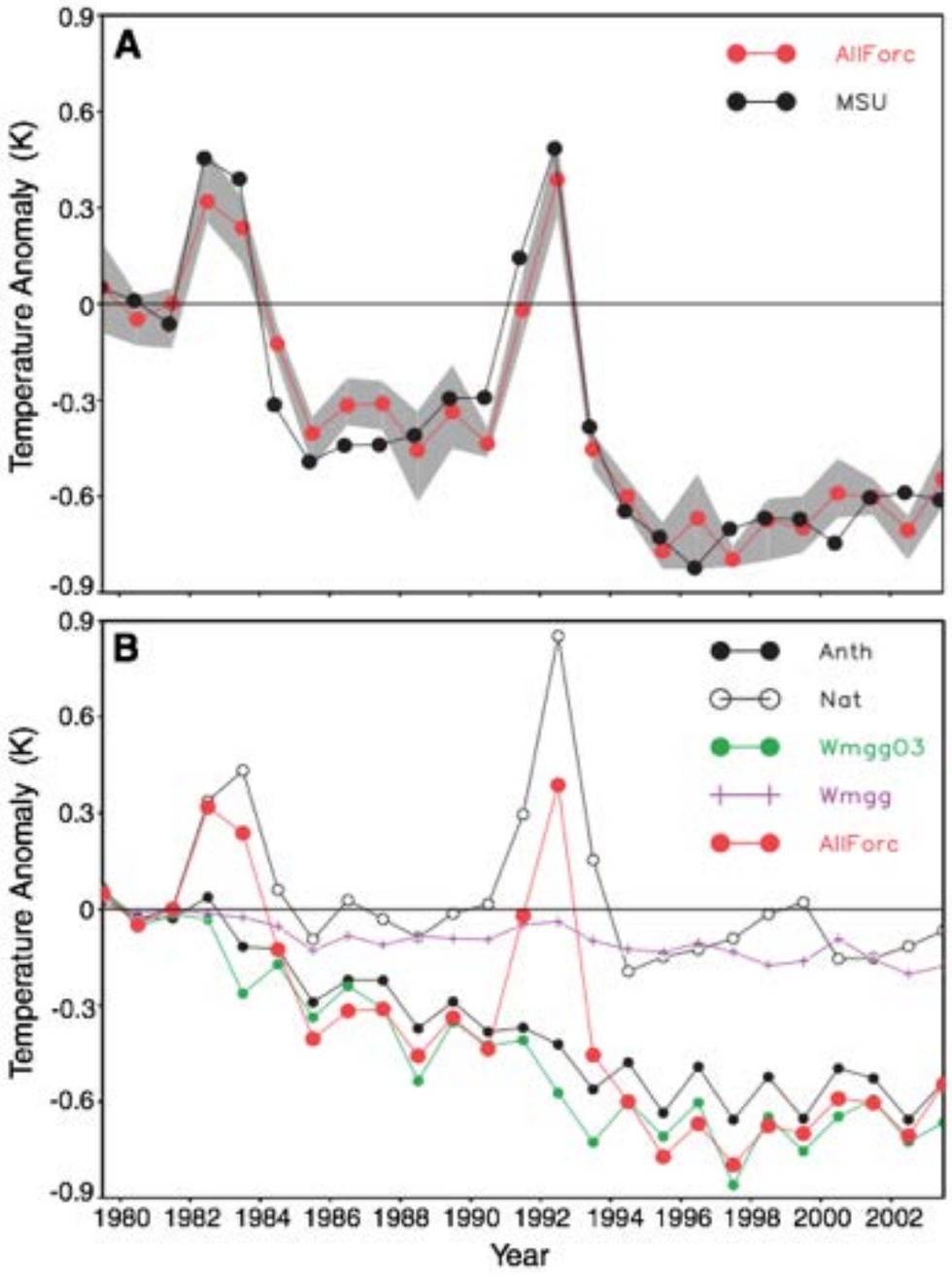


Thompson et al. (2012)

- General cooling since 1979 at all altitudes
- Cooling takes place in 2 steps at all altitudes: 1984-1991, 1995-today
- Warming centered around year 2000 in the SSU channels
- Short term warming due to volcanic eruptions

Attributing temperature changes to different forcing mechanisms

Lower stratospheric global temperature anomalies



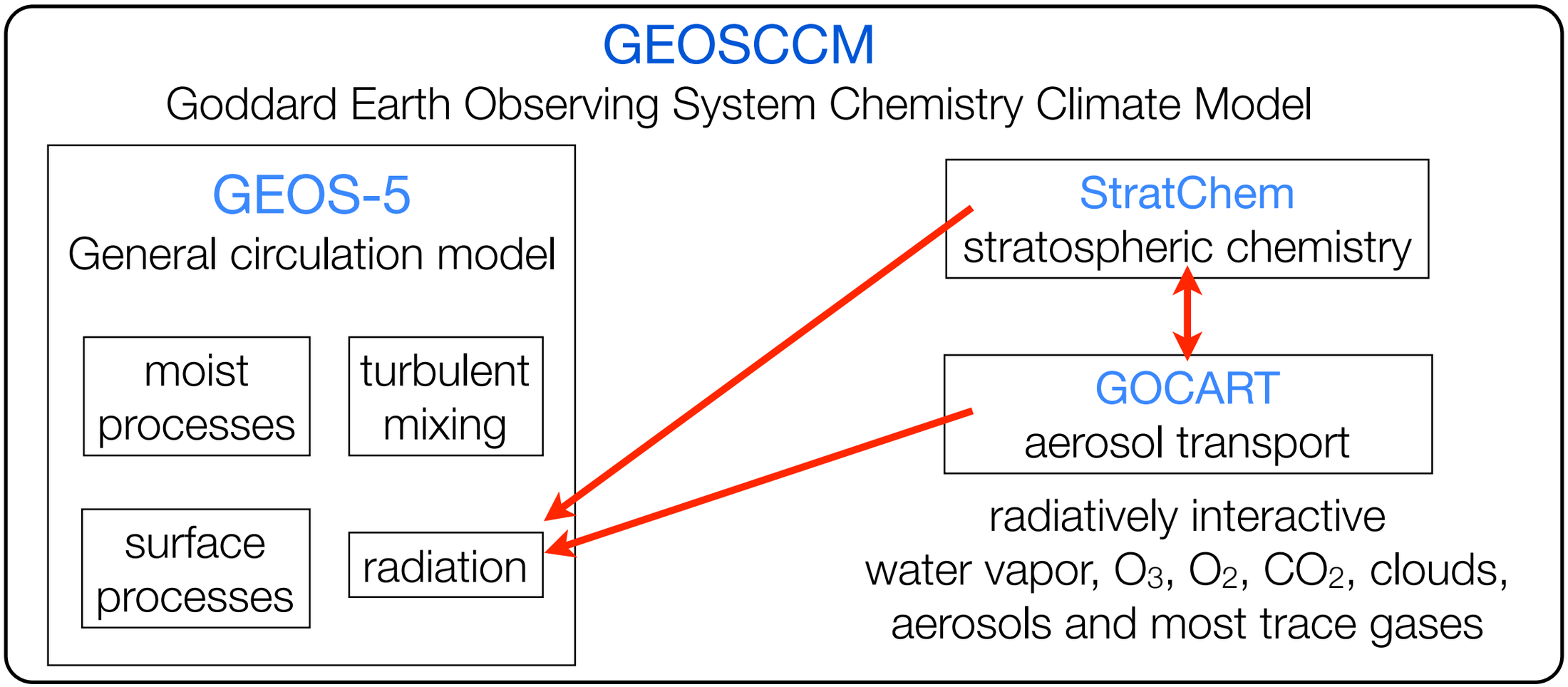
Ramaswamy et al. (2006)

- LS cooling since 1979 is of anthropogenic origin
- ΔT_{GHG} ~ -0.2K, ΔT_{ODS} ~ -0.5K
- Natural forcings modulate anthropogenic cooling

Goals:

- Extend these results to 2015 at all altitude levels
- Cleanly disentangle anthropogenic Vs natural contributions
- Identify the causes of features in the temperature record (steps, stalling, bumps…)
- Identify if there is a volcanic signature in signature temperatures since 2000

GEOSCCM



- Climate mode runs: forecast the climate starting from specified initial conditions
- Resolution: 2° latitude x 2.5° longitude, 72 vertical layers from surface to 0.01 hPa
- Aerosol and chemistry are coupled via heterogeneous chemistry
- QBO is internally generated via gravity wave parameterization
- Effects of solar cycles on radiation and ozone are included
- Prescribed SSTs from Hadley Center

Model simulations

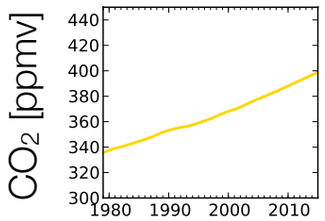
Simulated period: 1960-2015

3 ensemble members per experiment

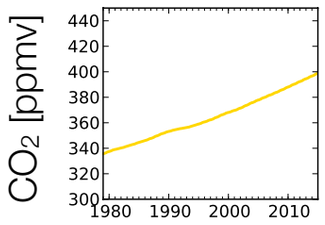
Climate mode runs: forecast the climate starting from specified initial conditions

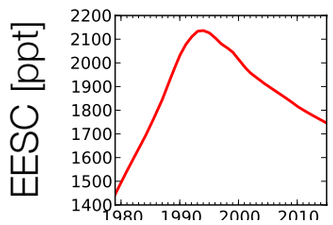
Four model experiments

1.SSTs + GHG

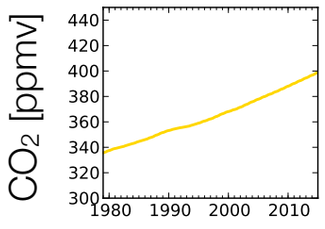


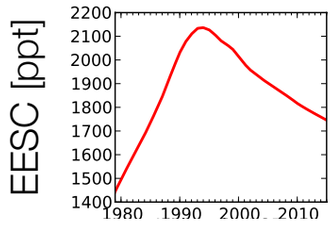
2.SSTs + GHG + ODS

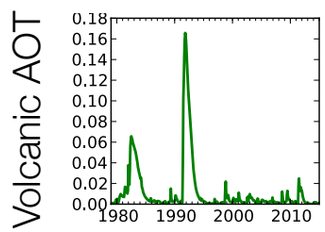




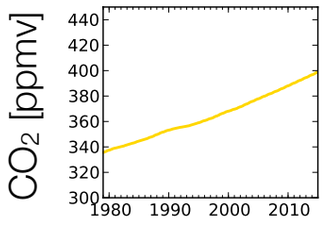
3.SSTs + GHG + ODS +volcanic eruptions (SO_2)

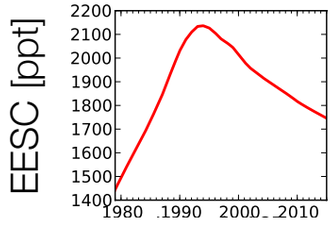


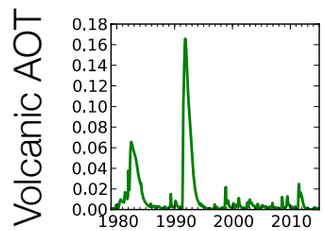


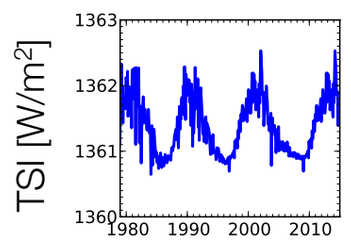


4.SSTs + GHG + ODS +volcanic eruptions + solar cycle

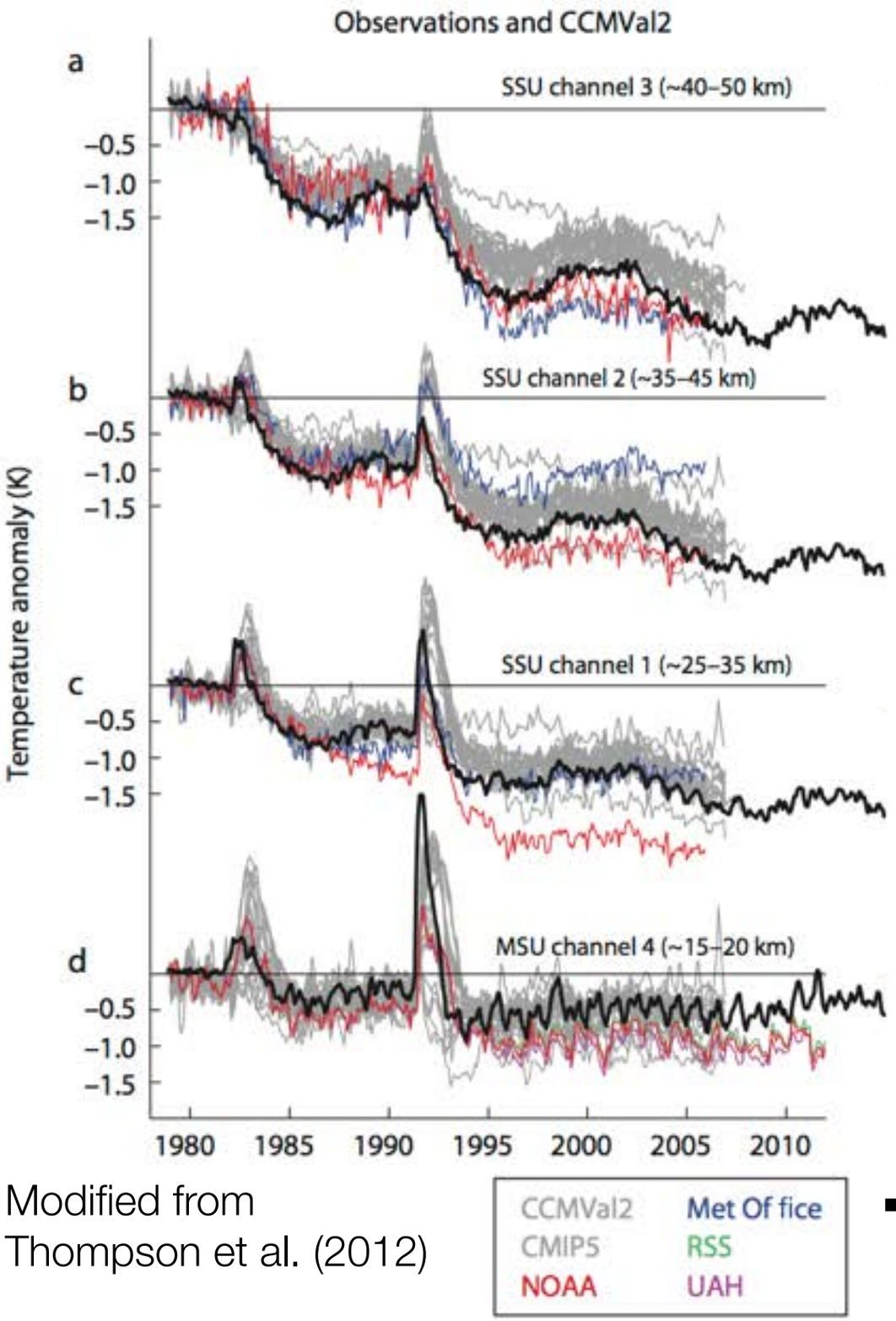








Observed and simulated global temperature anomalies

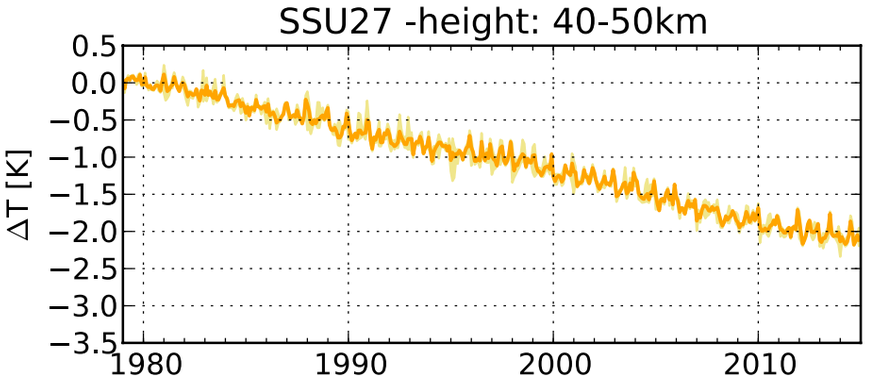


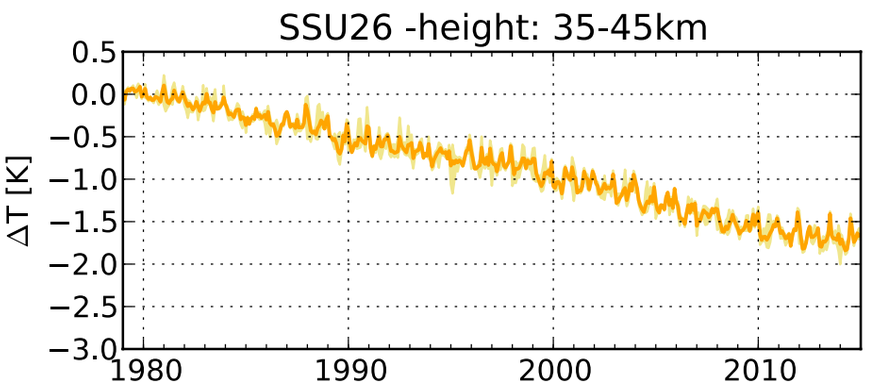
Modified from
Thompson et al. (2012)

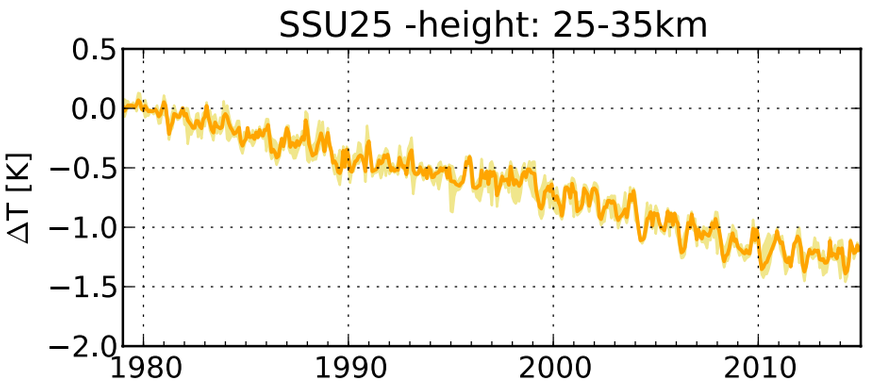
Results from the simulations with all forcings:
SSTs+GHG+ODS+volcanic eruptions+solar cycle

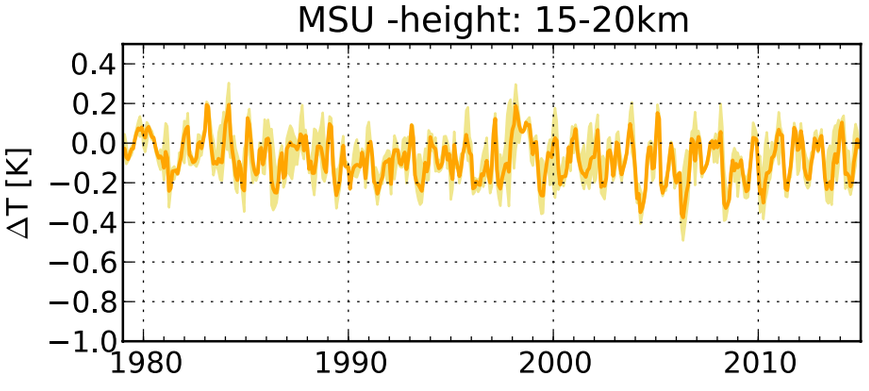
- GEOSCCM reproduces the pattern of stratospheric temperatures at all altitudes:
  - 2-step cooling
  - volcanic warming
  - warming around 2000
- In the lower stratosphere GEOSCCM underestimates the cooling by ~0.5K and overestimates the Mt. Pinatubo warming
- In the SSU channels GEOSCCM temperature anomalies are on the lower side of the CCMVal2 model results

Global temperature anomaly — GHG



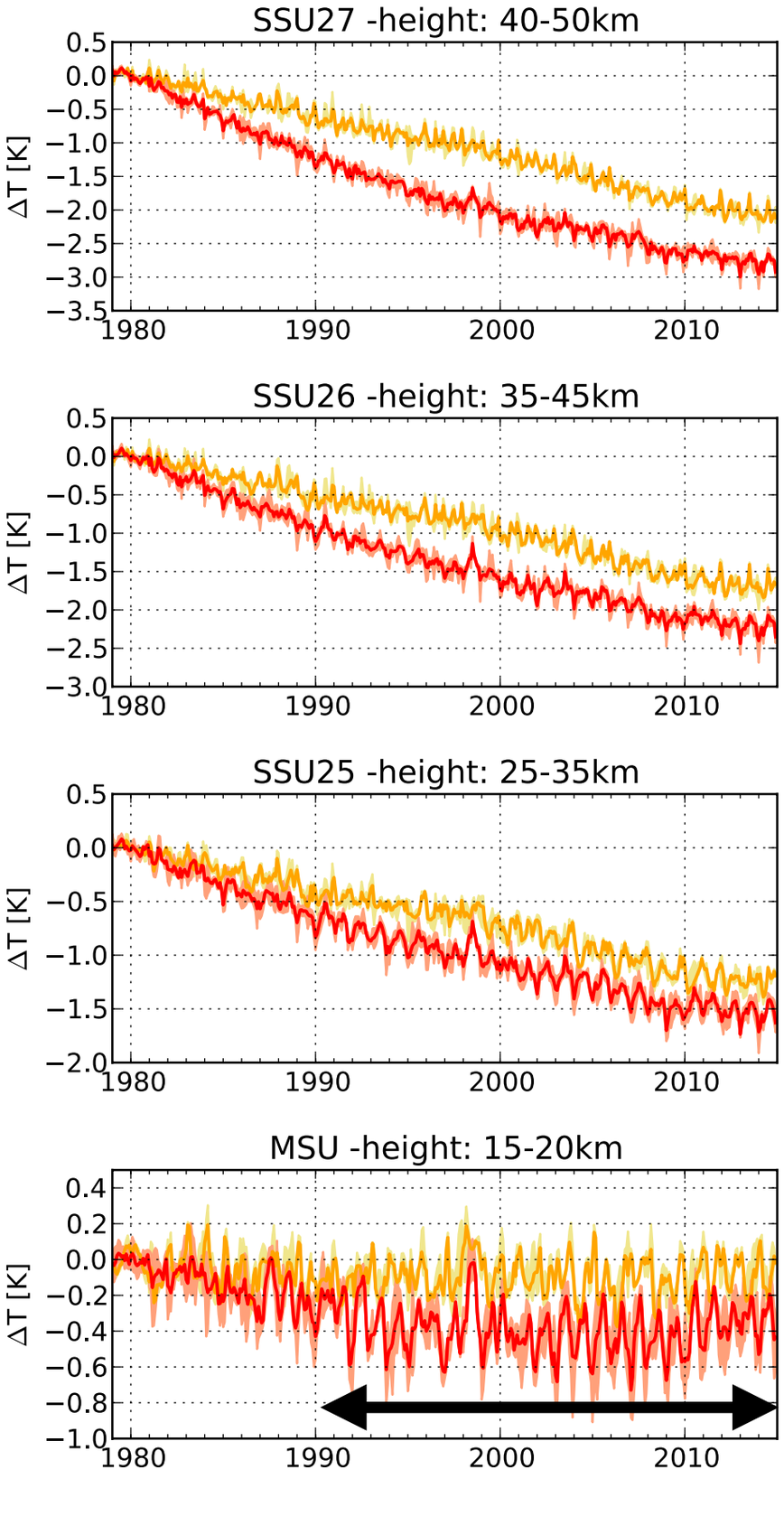




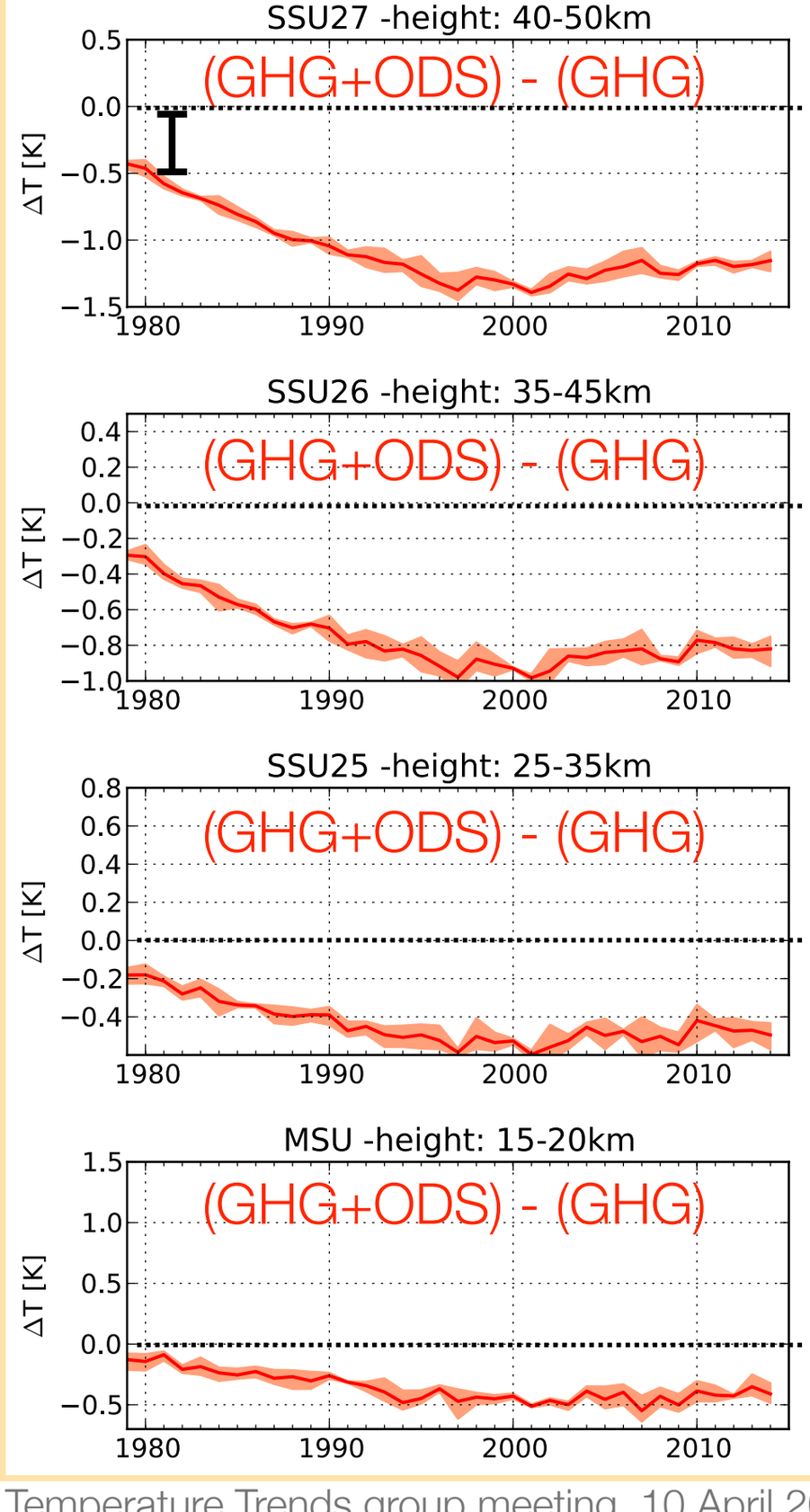


Global temperature anomaly

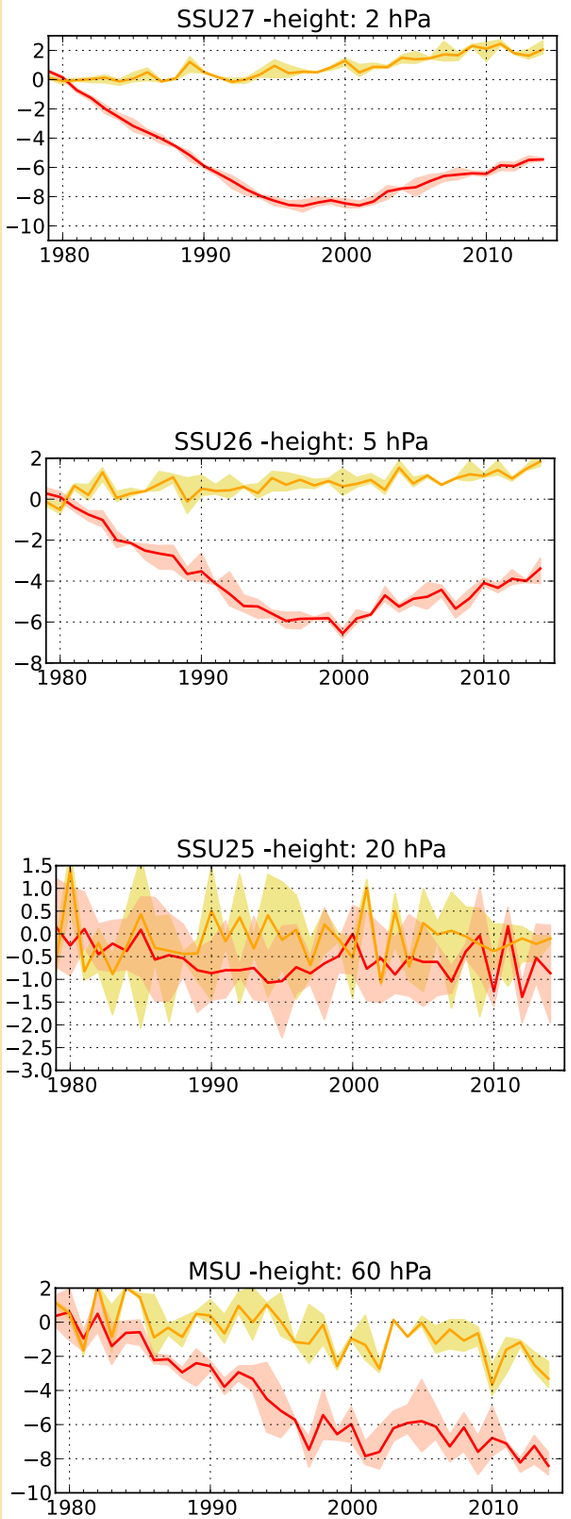
GHG
GHG+ODS



ΔT due to changing ODS

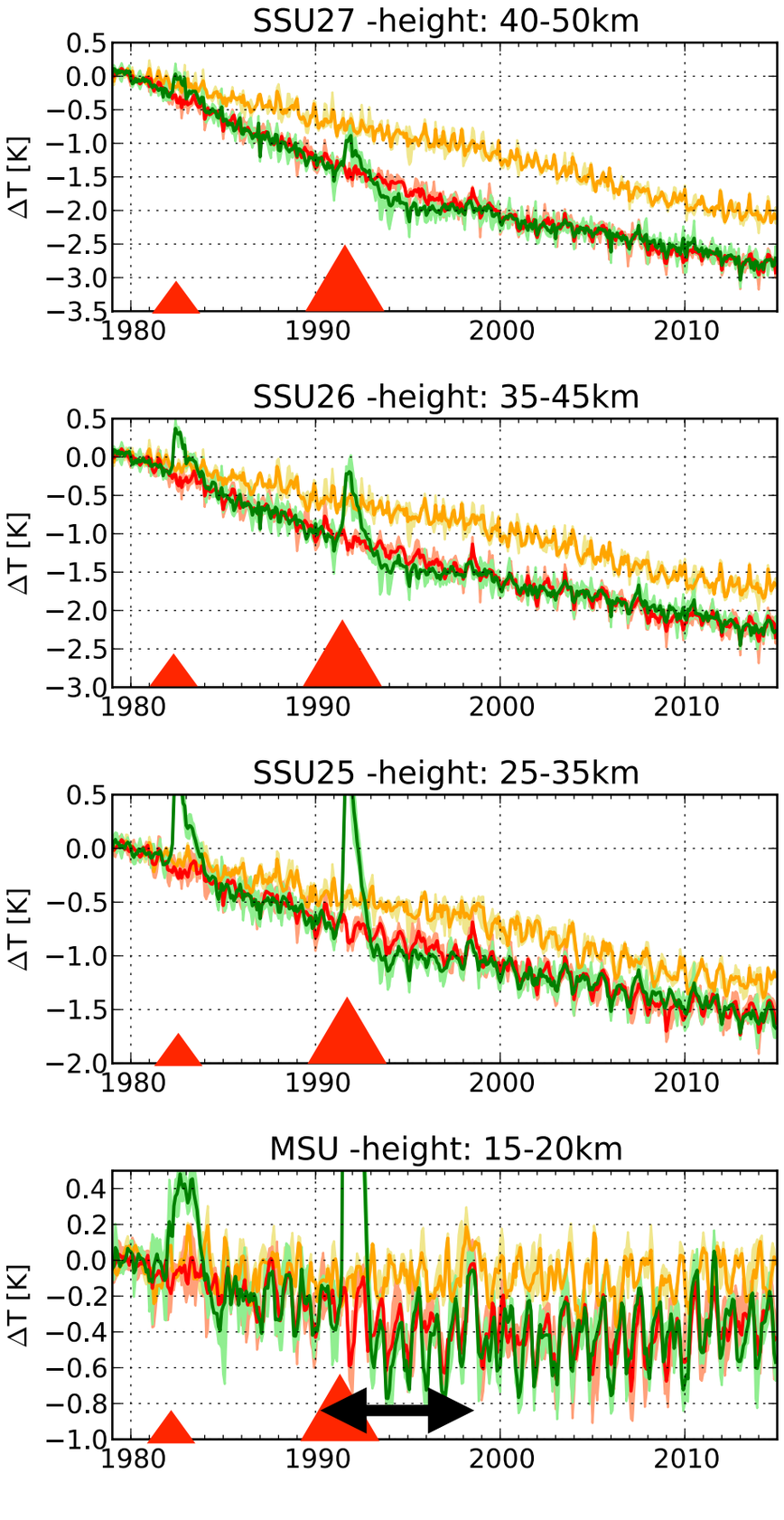


O_3 anomalies [%]

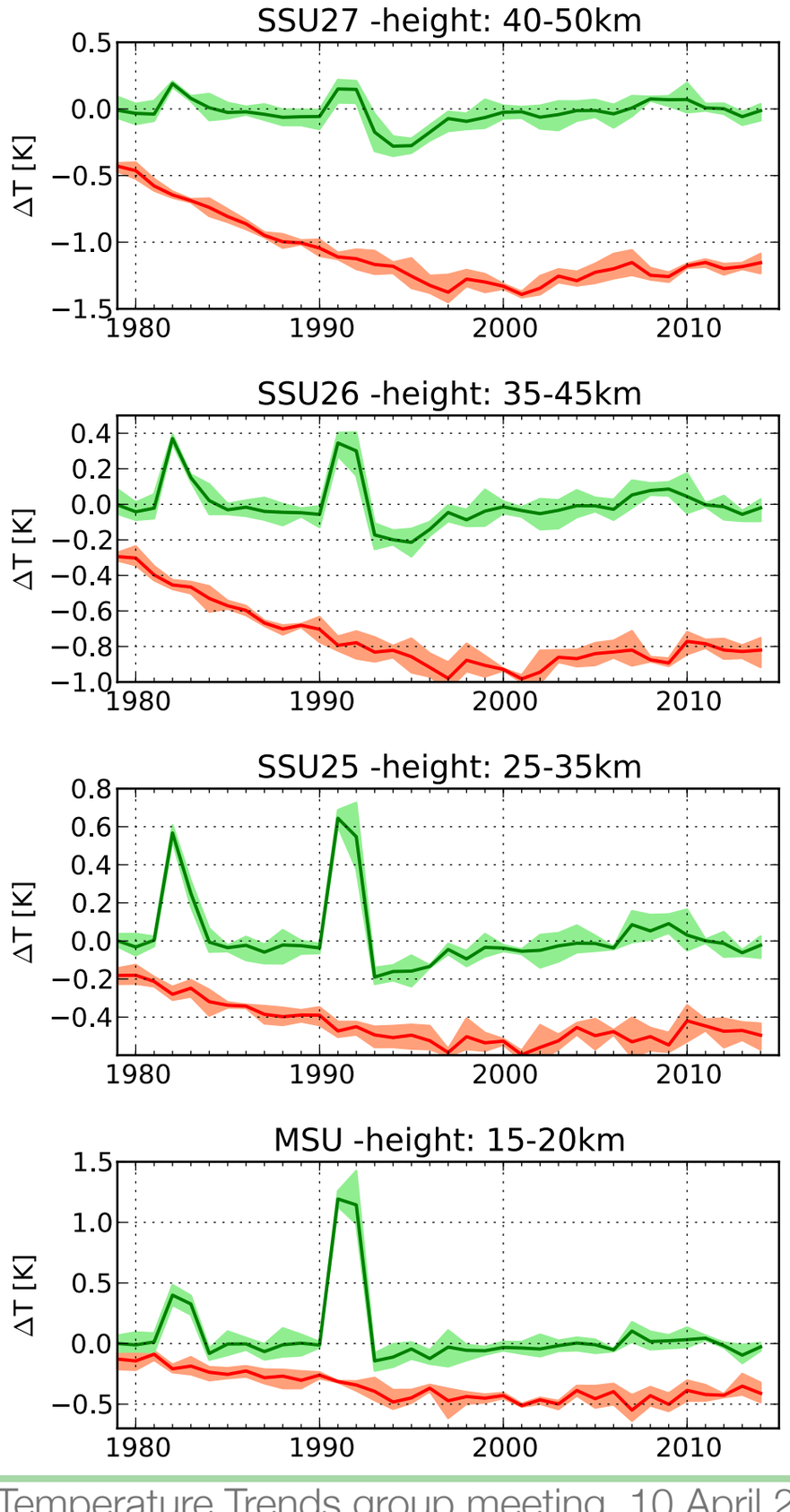


Global temperature anomaly

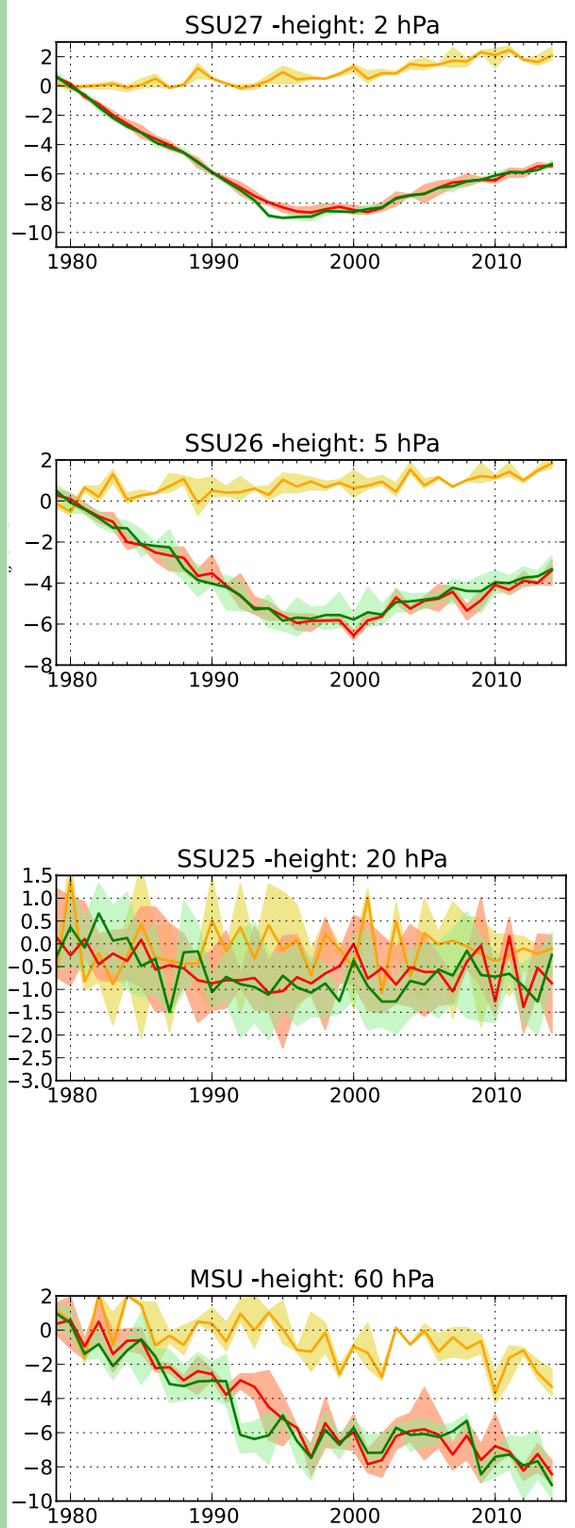
GHG
GHG+ODS
GHG+ODS+volc.



ΔT due to volcanic eruptions



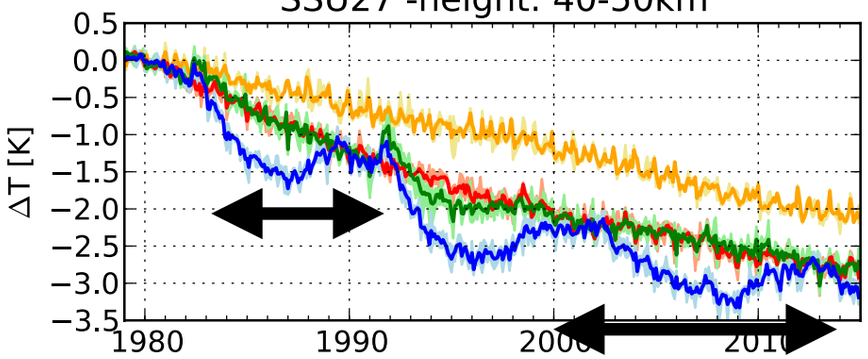
O_3 anomalies [%]



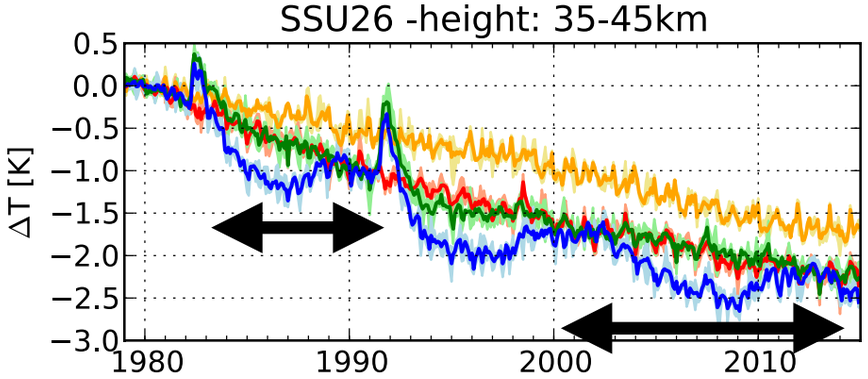
Global temperature anomaly

GHG
GHG+ODS
GHG+ODS+volcanoes
GHG+ODS+volcanoes+sun

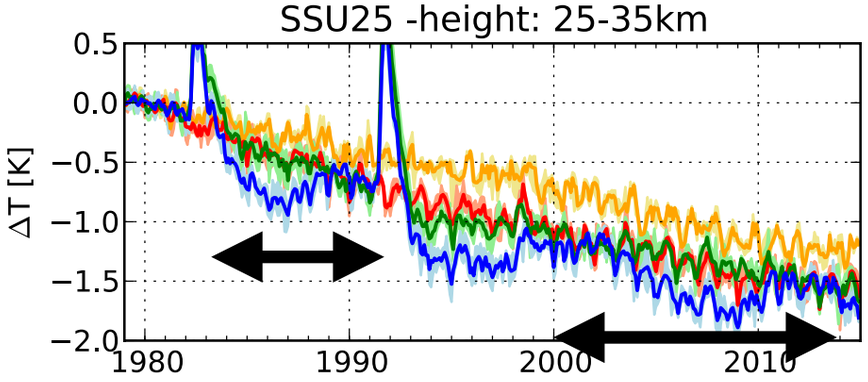
SSU27 -height: 40-50km



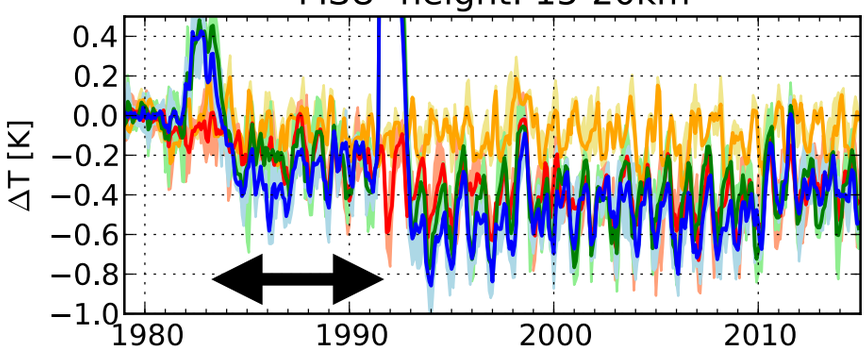
SSU26 -height: 35-45km



SSU25 -height: 25-35km

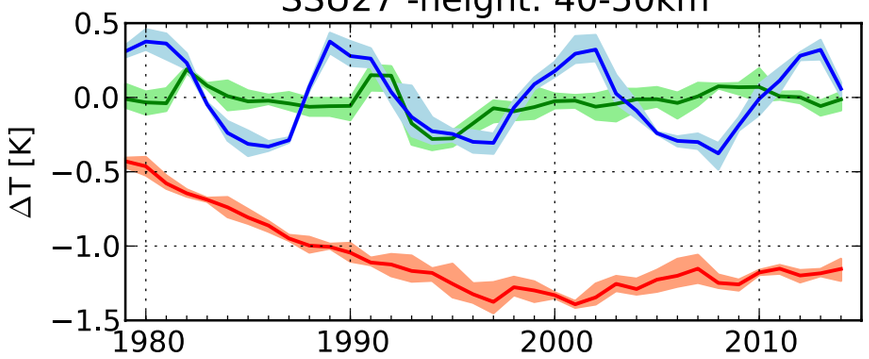


MSU -height: 15-20km

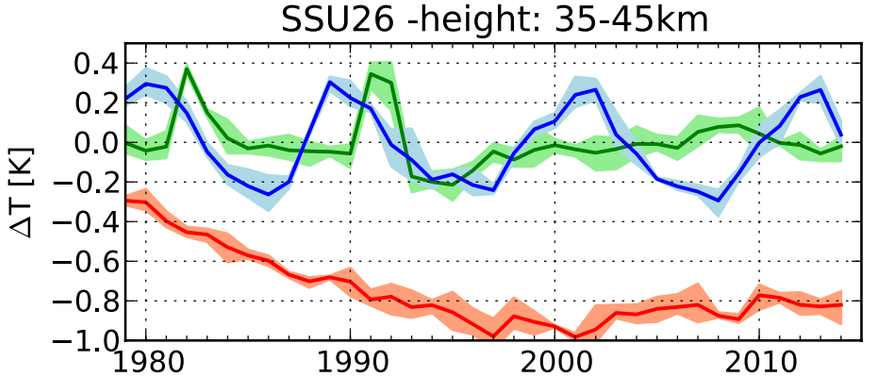


ΔT due to solar cycle

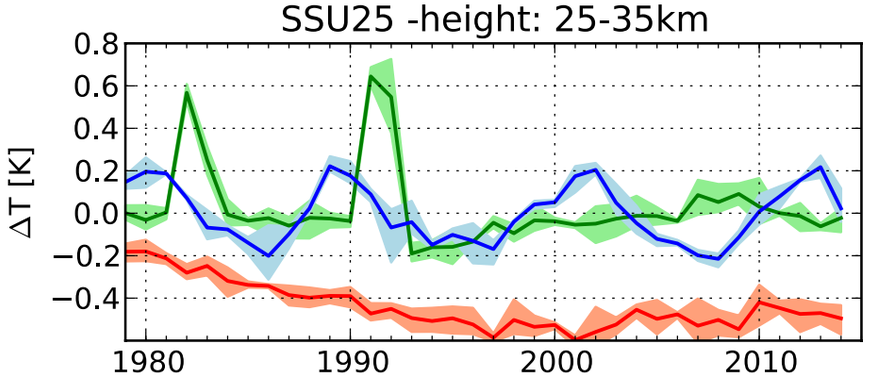
SSU27 -height: 40-50km



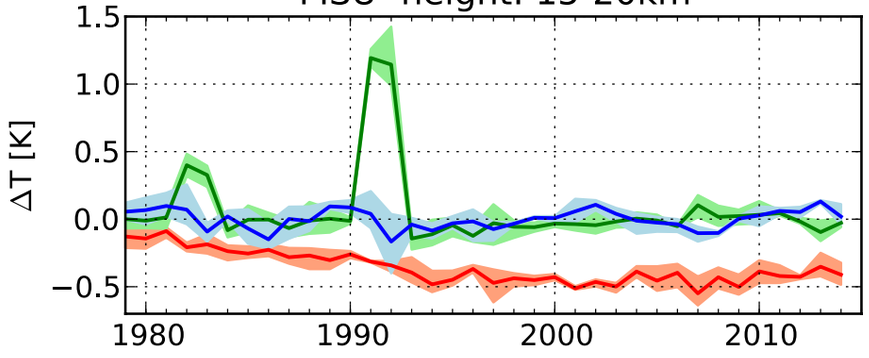
SSU26 -height: 35-45km



SSU25 -height: 25-35km

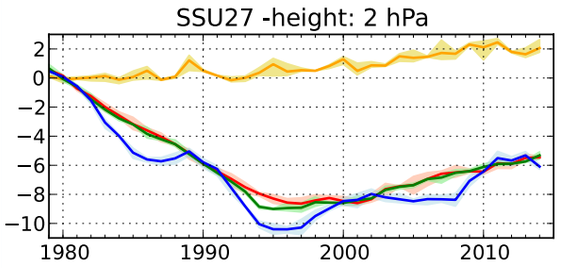


MSU -height: 15-20km

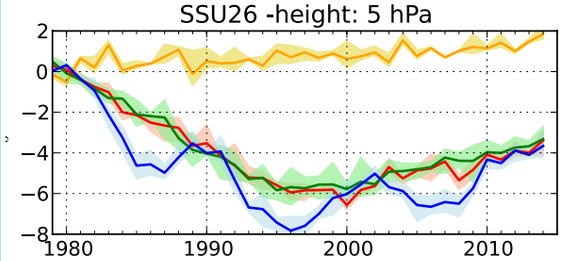


O_3 anomalies [%]

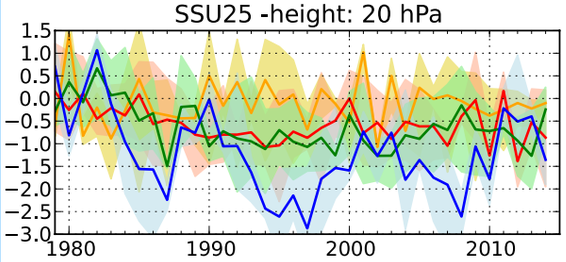
SSU27 -height: 2 hPa



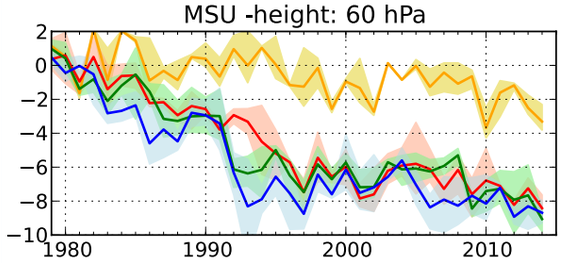
SSU26 -height: 5 hPa



SSU25 -height: 20 hPa

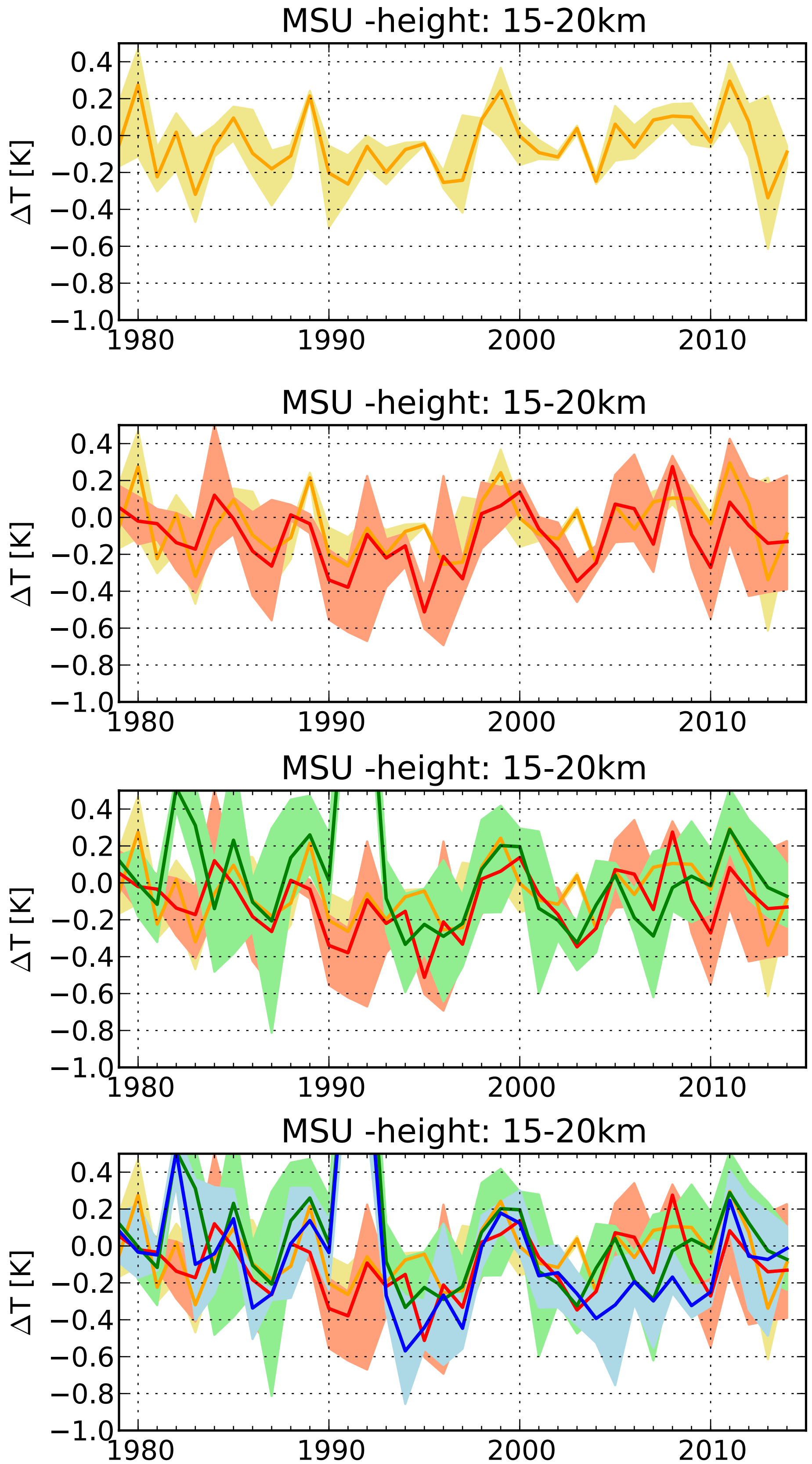


MSU -height: 60 hPa



Tropical temperatures

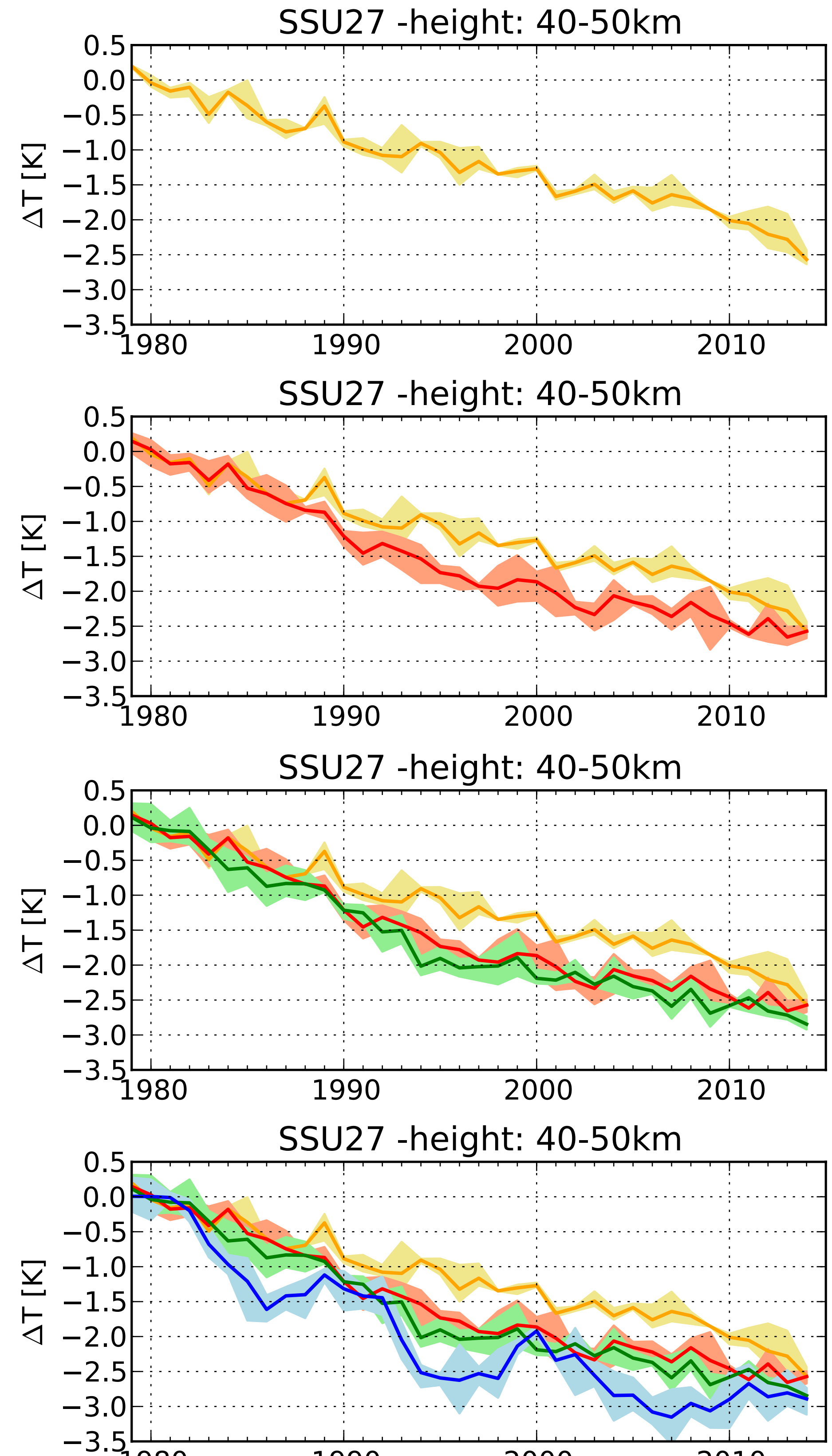
GHG
GHG+ODS
GHG+ODS+volcanoes
GHG+ODS+volcanoes+sun



Anomalies with respect to 1979-1982

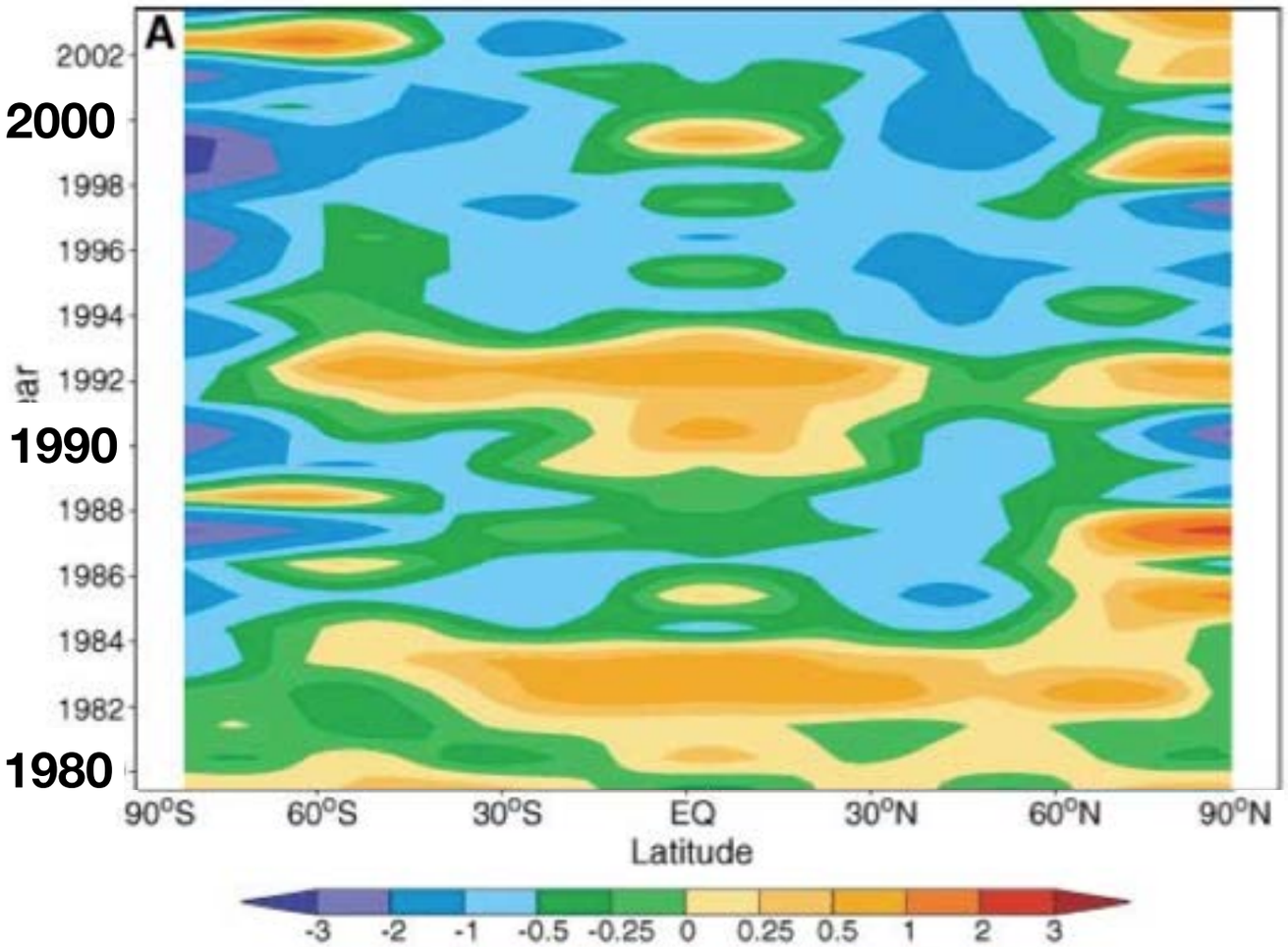
MSU channel:
No trend in LS temperature anomalies.

SSU27 channel:
Most cooling due to GHG.
ODS contributes up to 20%.
Solar cycle contributes up to 30%.



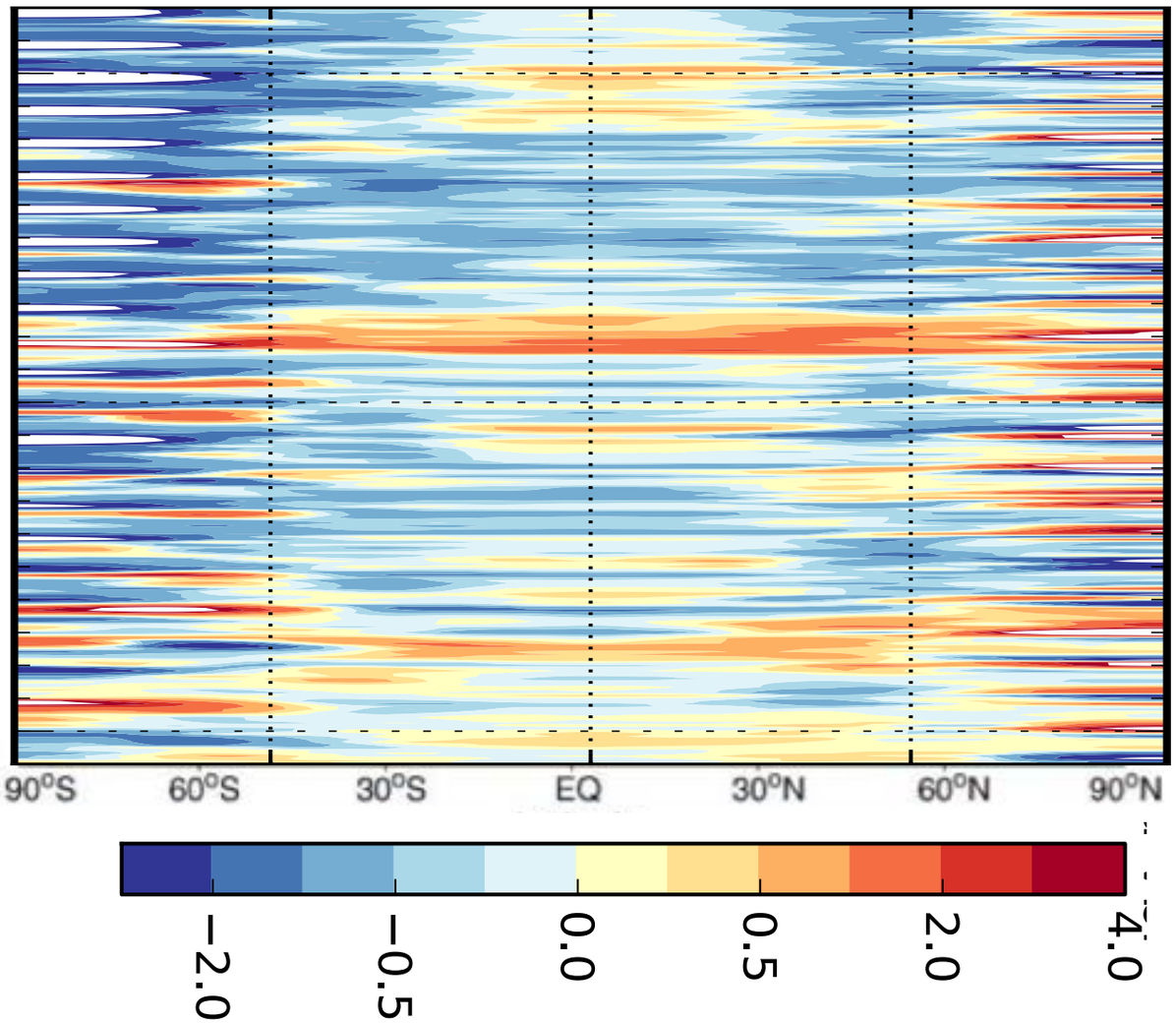
Lower stratospheric zonal mean temperature anomalies

Observations



Ramaswamy et al. (2006)

GEOSCCM

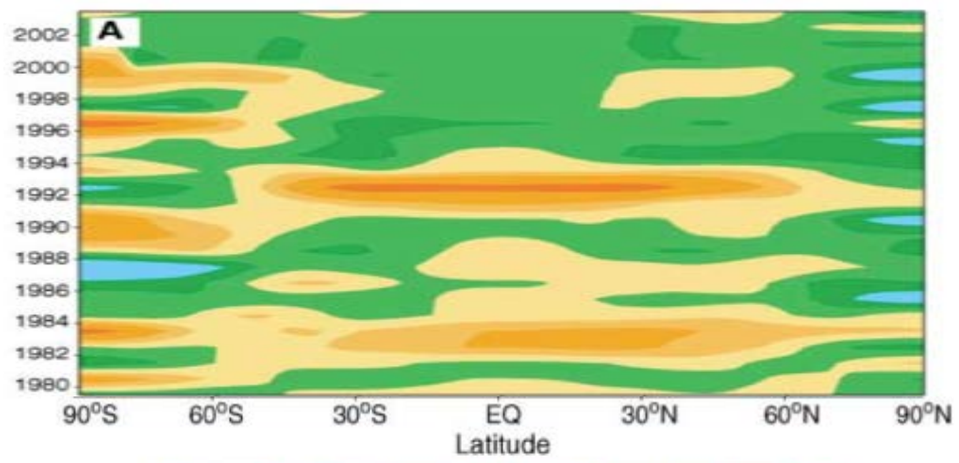


- General cooling at midlatitudes
- Warming at all latitudes post Mt. Pinatubo and El Chichon
- Mostly cooling at Southern high latitudes

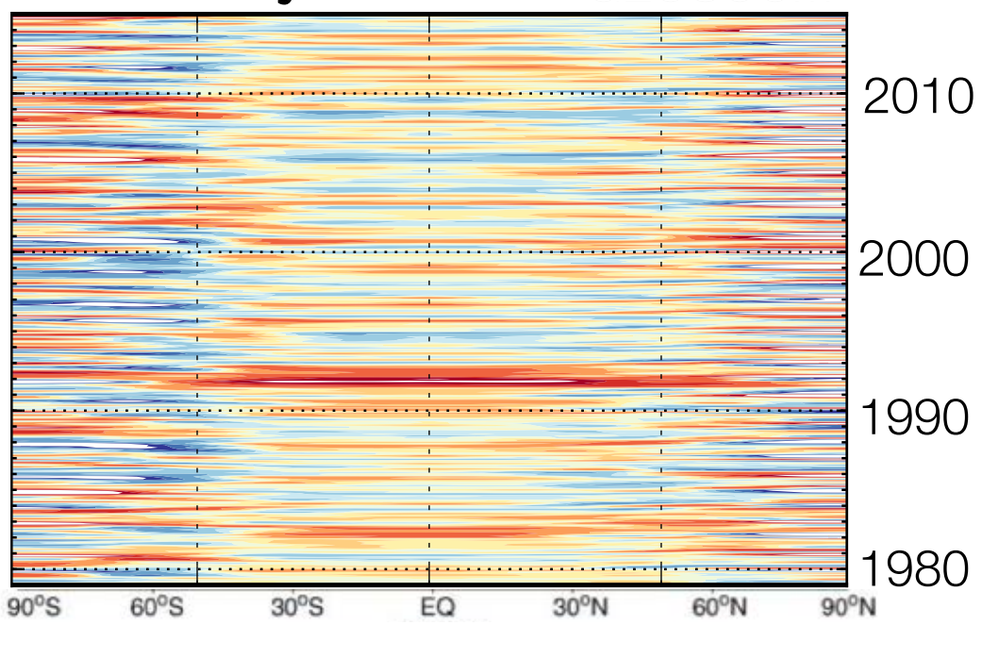
Lower stratospheric zonal mean temperature anomalies

Natural
(Volcanoes + Solar cycle)

Ramaswamy et al. (2006)

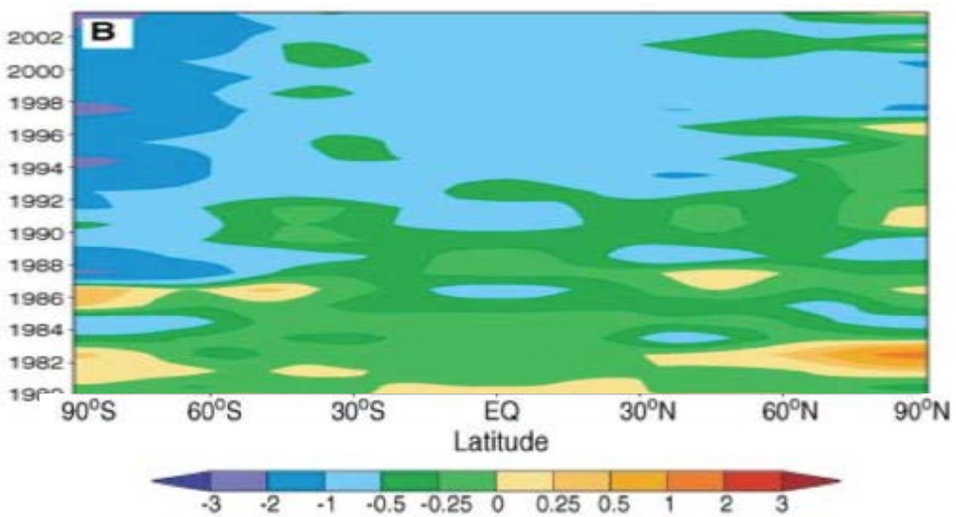


GEOSCCM

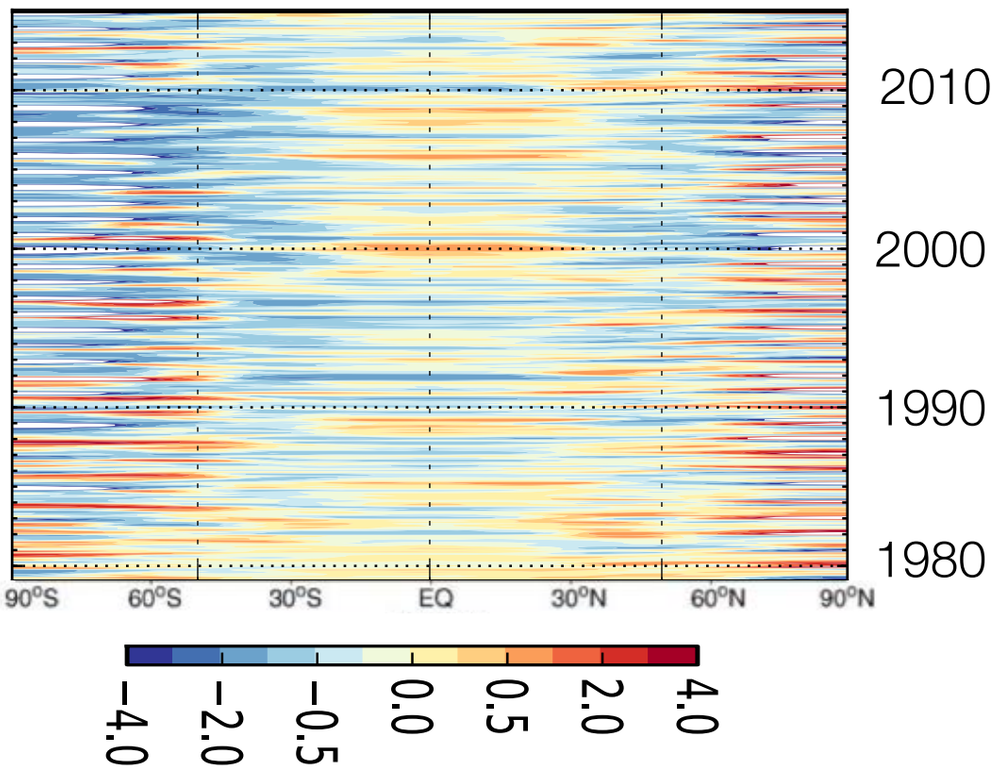


Anthropogenic
(ODS+GHG)

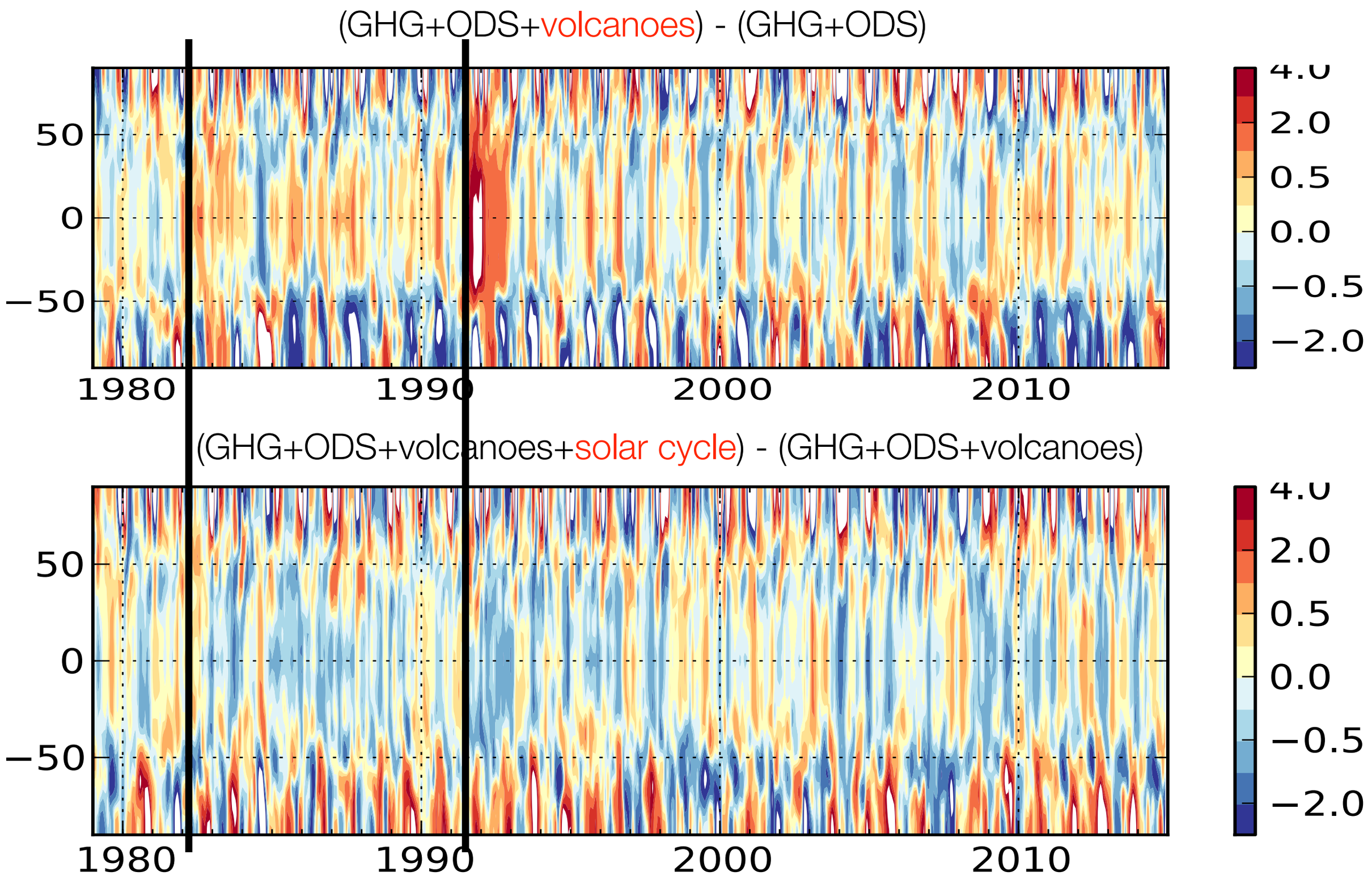
Ramaswamy et al. (2006)



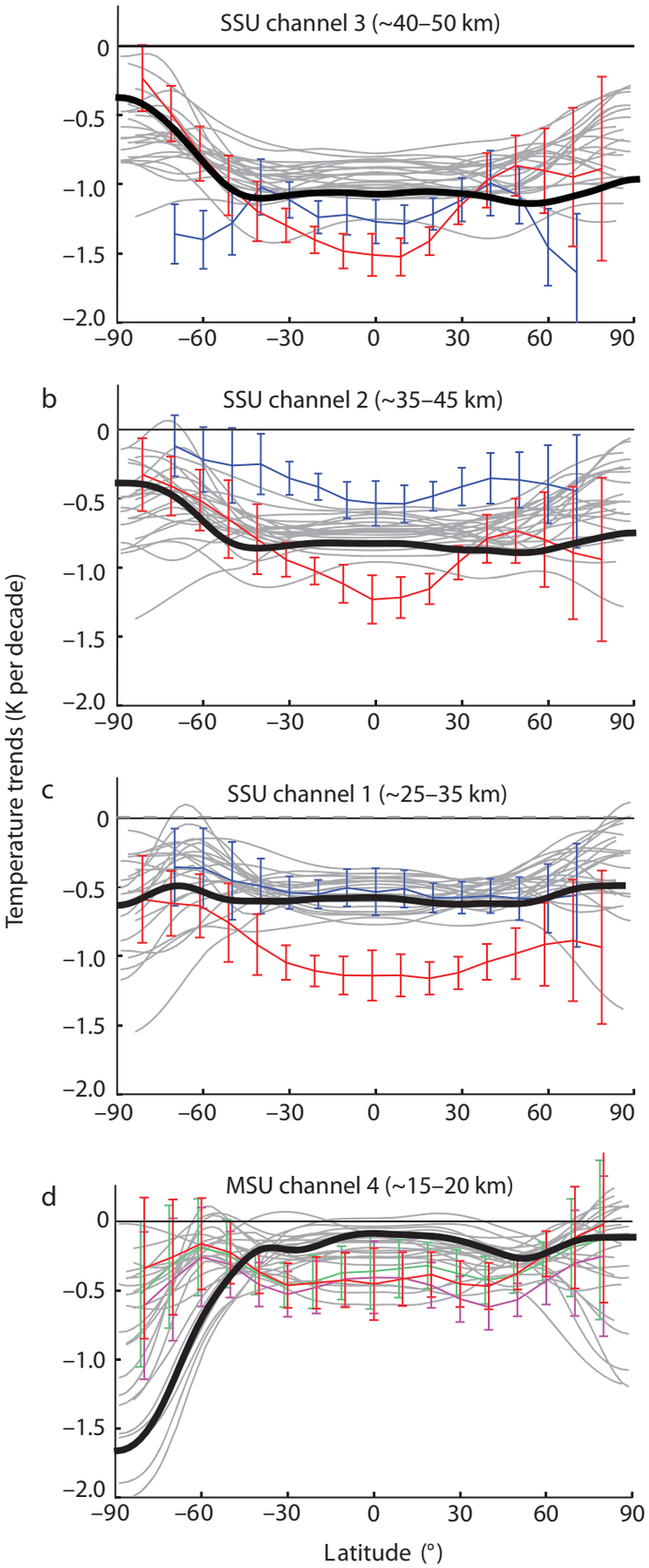
GEOSCCM



Zonal mean lower stratospheric temperature anomalies



1975-2005 temperature trends [K/decade]



Results from the simulations with all forcings:
SSTs+GHG+ODS+volcanic eruptions+solar cycle

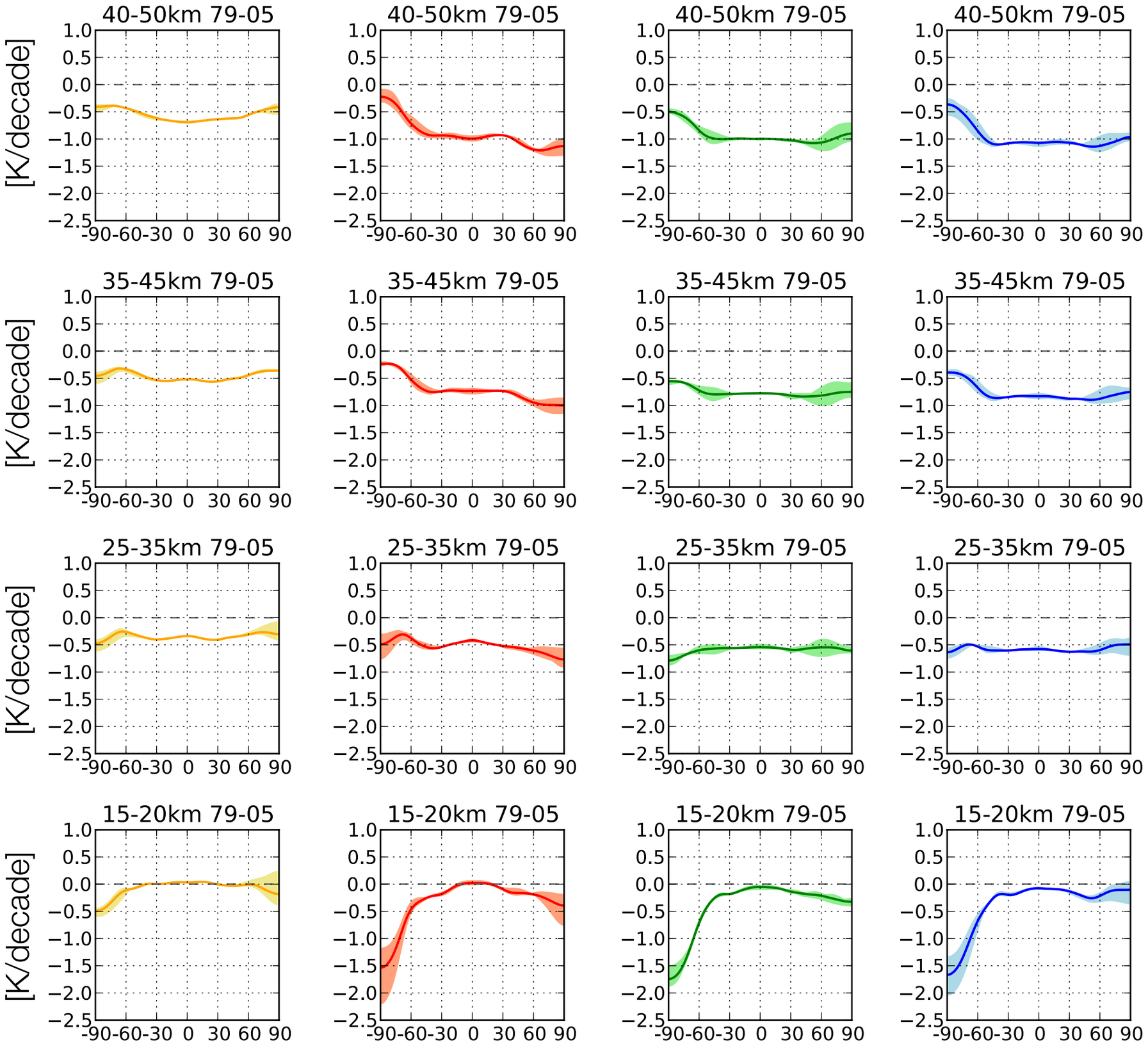
- MSU channel:
  - underestimate tropical trend
  - overestimating SH high latitude trend.

- SSU channels:
  - Flat profile between 40°S-40°N.
  - Underestimating tropical trends.
  - Trends at southern high latitudes are well reproduced.

Modified from
Thompson et al. (2012)

Temperature trends

GHG
GHG+ODS
GHG+ODS+volcanoes
GHG+ODS+volcanoes+sun

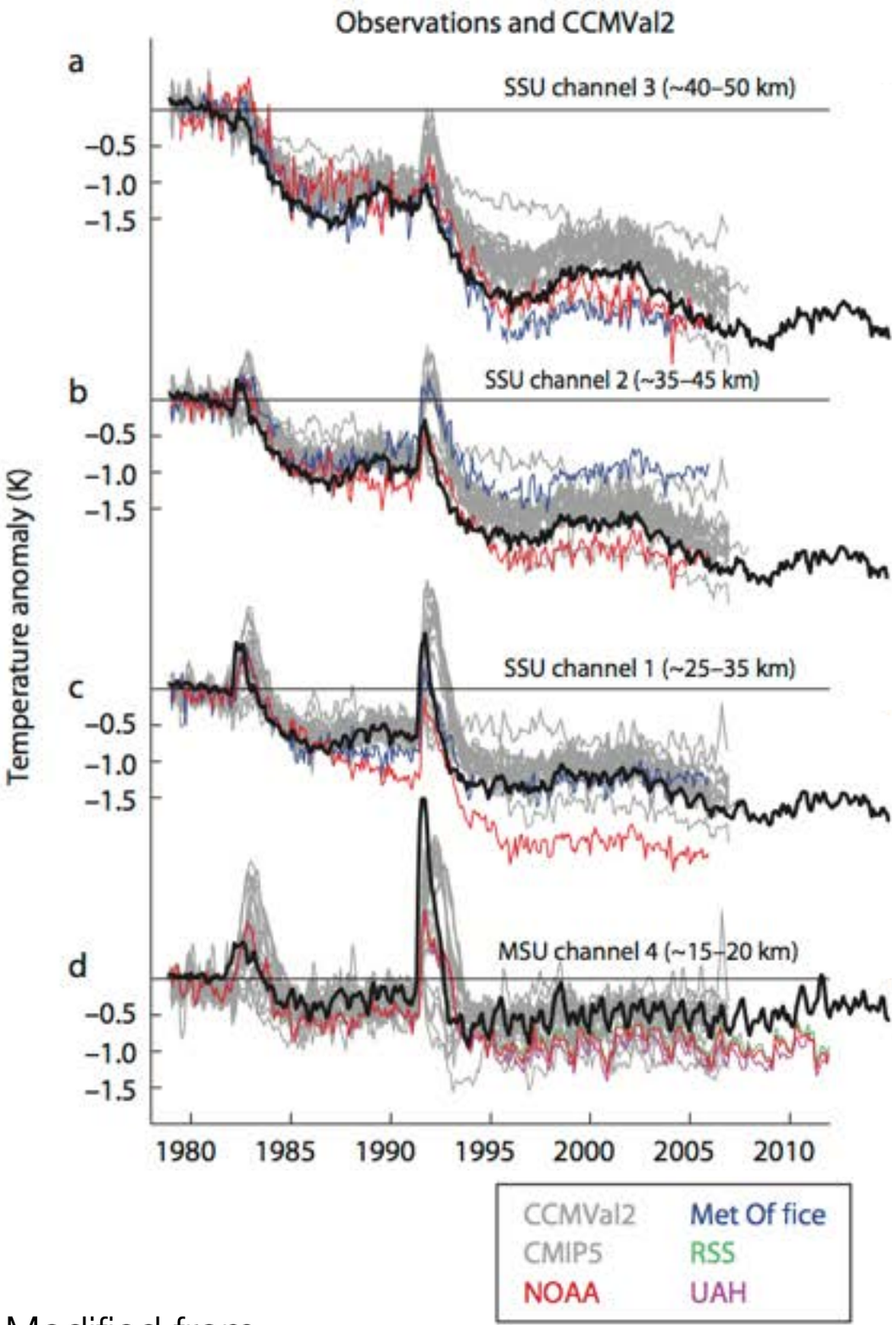


1979-2005 trends

Changing ODS:
Increased tropical cooling above 35 km.
Increased LS cooling in the SH.

Natural forcings:
No effects on trends

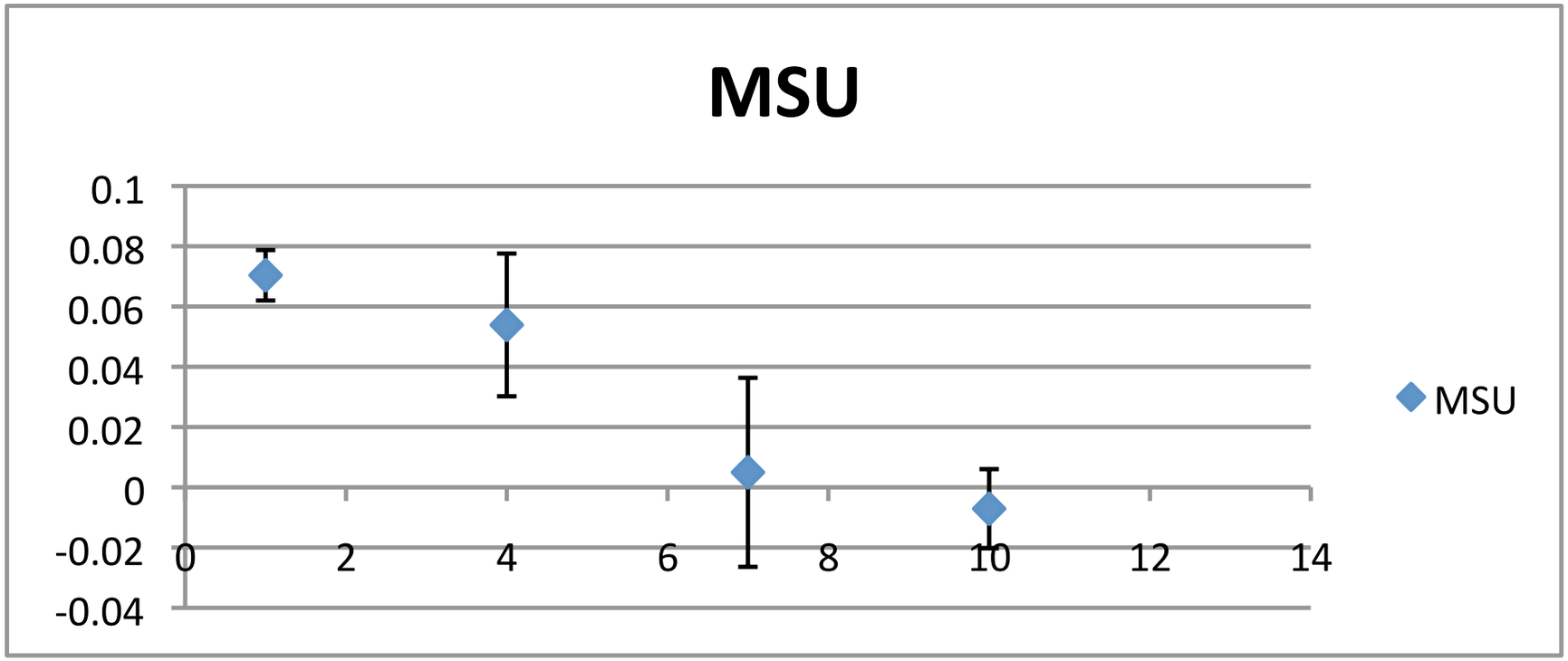
Conclusions



Modified from Thompson et al. (2012)

- GEOSCCM well reproduce stratospheric temperature patterns.
- The flattening of LS global temperatures anomalies past 1995 is a signature of the Montreal Protocol. At higher altitude is an effect of the solar cycle.
- The solar cycle causes the step in stratospheric global temperature anomalies after El Chichon.
- There is no long term trend in LS temperatures caused by volcanic eruptions after Mt. Pinatubo… maybe.
- GEOSCCM shows no trend in LS tropical temperature anomalies, but a cooling trend in the SSU channels caused mainly by GHG.

1995-2015 Trends



GHG+ODS+Volc+Sun

GHG+ODS+Volc

GHG+ODS

GHG